Abstract

Currently used prostheses for total joint replacement still have numerous disadvantages: extreme stiffness or elastic modulus of the bulk metallic material; insufficient integration of the implant into the host bone; and a high wear and corrosion rate, which causes an accumulation of mostly metallic or polymeric wear debris. Because of these reasons, many patients experience increasing local pain, swelling, allergic reactions, and inflammation resulting in bone loss and the aseptic loosening of the implant leading to the need for painful and expensive revision surgery.

To address the mechanical issues of commonly used orthopaedic alloys, this thesis presents the development of the new β-type titanium alloy Ti-35Nb-7Zr-6Ta-2Fe-0.5Si with a relatively low elastic modulus (up to 85 GPa), increased tensile strength (880 MPa), and enhanced biocompatibility and osteoconductivity.

Considering the generally low osteoinductivity of metallic implants, various surface modifications and coatings have been developed to improve the cell-material interaction, e.g. carbon-based coatings. Among these coatings, C_{60} fullerene layers have emerged as a great candidate for coating orthopaedic implants due to their therapeutic potential in arthritis. The potential cytotoxicity and DNA damage response of fullerenes have been evaluated. Although the fresh C_{60} coating has attenuated the adhesion and proliferation of cells, no DNA damage or signs of cytotoxicity have been found. The biocompatibility of C_{60} films has improved with the increasing age of these films or by co-deposition of C_{60} molecules with Ti atoms, thanks to changes in their physicochemical properties (such as fragmentation, oxidation, polymerization and graphitization).

In order to minimize the wear and corrosion of the Co-Cr-Mo alloy, the diamond-like-carbon (DLC) coating of this alloy with a titanium gradient adhesive interlayer has been used. The wear analysis has revealed no visible wear or delamination of the DLC coating after 3 million cycles of increasing loading force of up to 2.5 kN. Moreover, no proof of any cytotoxicity of the potential wear debris has been found.

In the last project of this thesis, a biocompatible, fully optically transparent diamond-based planar biosensor for the non-invasive (label-free), real-time monitoring of cell cultivation has been successfully invented. The main advantage of this sensor is its transparency, which enables microscopic native cell observation and the wide frequency range of the sensor allowing the detailed study of different cellular processes.